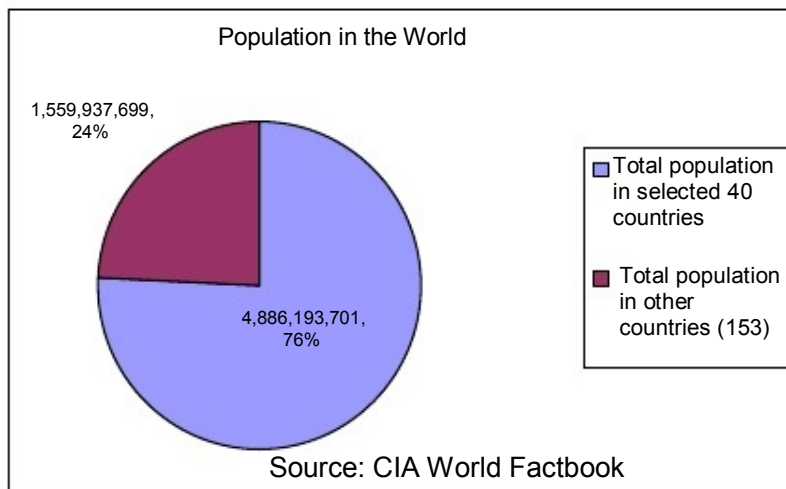# How electricity consumption affects social and economic development by comparing low, medium and high human development countries

The objective of this paper is to show that increasing electricity consumption per capita can achieve improved social development and faster economic growth. We have selected a group of 40 high, medium, and low human development countries based on United Nations Development Programme (UNDP) data. These nations comprised 76% of the global population. Then, we performed a statistical analysis using a standard regression test to determine the relationship between electricity consumption per capita vs. key social and economic development indicators in these 40 countries. After we run and analyze a few statistical regression tests using all 40 countries, we determine that we should exclude the high human development countries and four outliers (Russian Federation, Saudi Arabia, South Africa and Zimbabwe) in our further regression analysis. Finally, when we completed our empirical analyses, we are confident that increasing electricity consumption per capita can directly stimulate faster economic growth and indirectly achieve enhanced social development--especially for medium and low human development countries. The threshold for moving from a low to medium human development economy appears to transition when 500kwh per capita is attained. Electricity plays a key role in development.

I. Introduction

There are 193 countries in the world (Geography.About.com web site). Ten of the forty countries that we selected are the ten most populous countries in the world, constituting approximately 59.2% of the global population. The remaining 30 countries make up approximately 16.6% of global population and are economically significant in their respective continents. Therefore, these 40 countries (which are listed in table 1) represent approximately 76% of global population. This chart illustrates the population data (See the attached Excel file for more detail on each of 40 countries' population).

Population in the World

1,559,937,699, 24%

4,886,193,701, 76%

Total population in selected 40 countries

Total population in other countries (153)

Source: CIA World Factbook

Even though only 40 out of 193 countries were chosen for our statistical sample, the sample size is sufficient due to the high global population representation and relative economic significance.
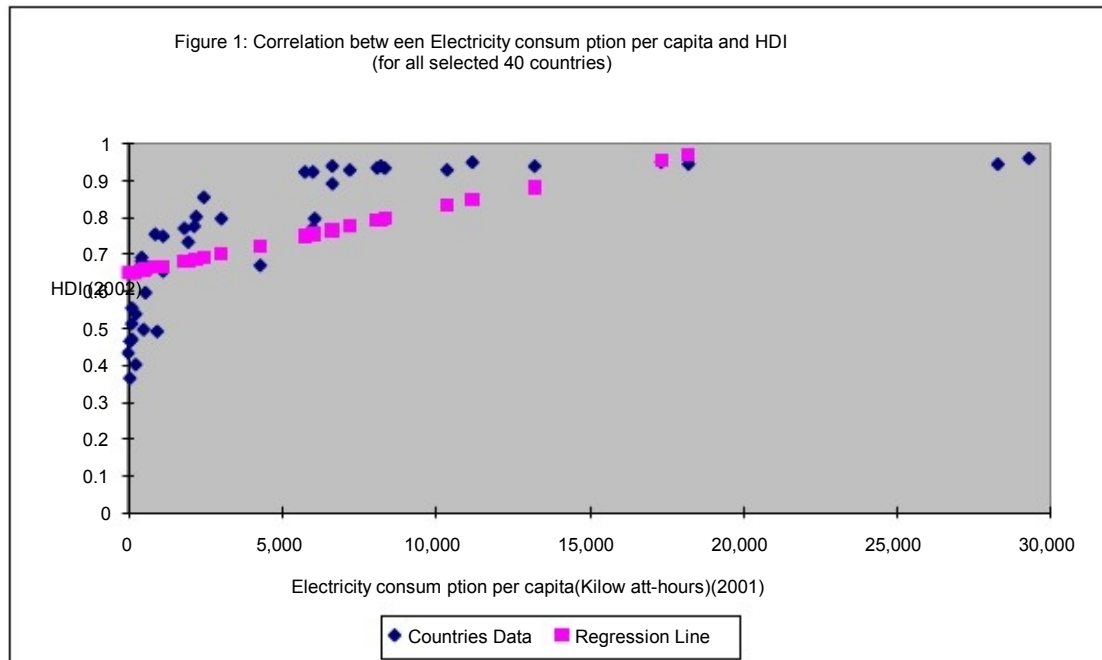
We begin, in section II, by running a statistical test (comparing electricity consumption per capita to the Human Development Index (HDI is a component of three indexes; the Life Expectancy index, Education index and GDP index)) and analyzing the result. It helps us to take out four outliers that make our statistical tests less significant. Then, we give an explanation why we consider these countries are outliers. In section III, we do several regression tests to analyze the correlation between electricity consumption per capita and other important indicators (both social and economical) using the data without the outliers. Sections IV and V give a summary and conclusion on how increasing electricity consumption per capita affects social and economic development indicators.

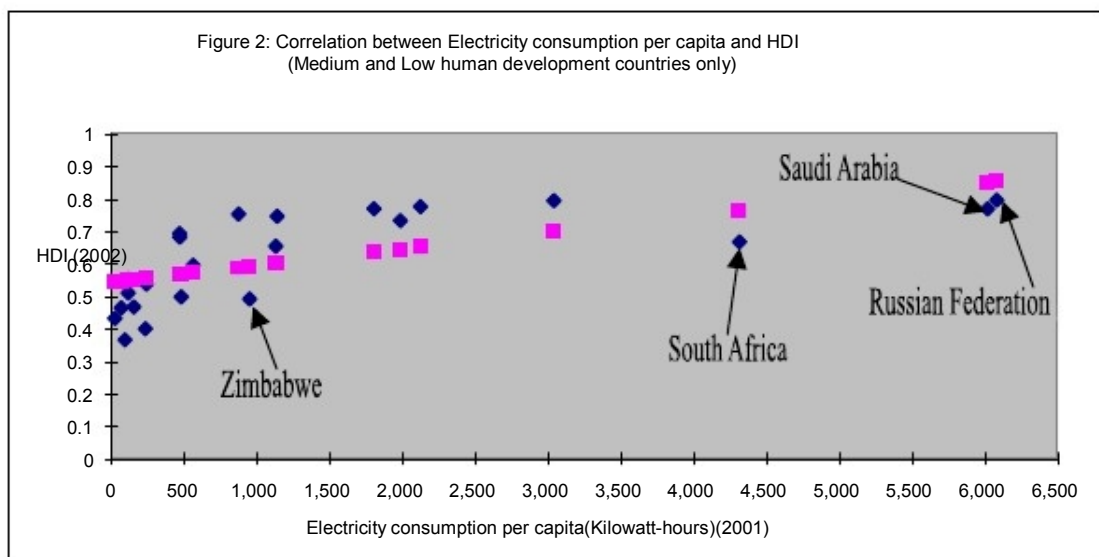II. Empirical evidence for the statistical analysis of Human Development Index

HDI compared to Electricity Consumption per capita

We have run a regression test to analyze the correlation between the HDI and Electricity Consumption per capita for 40 countries. The R-square is 0.4615, which tells us that 46.15% of the variation in the HDI is explained by the variation in the electricity consumption per capita. The coefficient of determination (R-square) merely supplies us with a measure of the strength of that relationship. The standard error is 0.1399, which is relatively high given the data (see Excel file for details). It shows us that there is not a strong relationship between the HDI and electricity consumption per capita for this data set. However, after we analyze the chart very carefully, we believe that this regression test is a poor model because a very small variation in HDI is being explained by a bigger variation in electricity consumption per capita for high human development countries.

Thus, it is important to exclude these high HDI countries in our analysis because the proportional change in HDI that results from changes in electricity consumption per capita is significantly different for high human development countries compared to low development countries. An increase in electricity consumption per capita may only cause the HDI index to rise only slightly for high human development countries because these countries already have a high HDI index. Additionally, the maximum HDI value is 1, as we can see that in figure 1 below. It became clear that we should exclude high human development countries in our model since these countries have already realized the gains from increased electricity consumption, which has a decreasing marginal return (each additional increase in unit of electricity consumption per capita results in a lesser increase in HDI).

Figure 1: Correlation betw een Electricity consum ption per capita and HDI
(for all selected 40 countries)

Upon reviewing the result above, we determined to exclude high human development countries in our model. Therefore, the regression test is run again with only medium and low human development countries (23 countries in all). The new R square is 0.4302, which is lower than the previous R square value of 0.4615. This result appears to not make sense. Also the standard error is 0.1092 which is still relatively high given the data. A careful look at the data reveals that four of the countries (Russian Federation, Saudi Arabia, South Africa and Zimbabwe) have very strange data. Zimbabwe has the second lowest life expectancy index and life expectancy at birth. The other three countries have very high electricity consumption per capita, but their HDI is relatively low. We can see these nations plotted in Figure 2. Also, we will discuss why these four countries show a very weak correlation later in this paper.

Figure 2: Correlation between Electricity consumption per capita and HDI
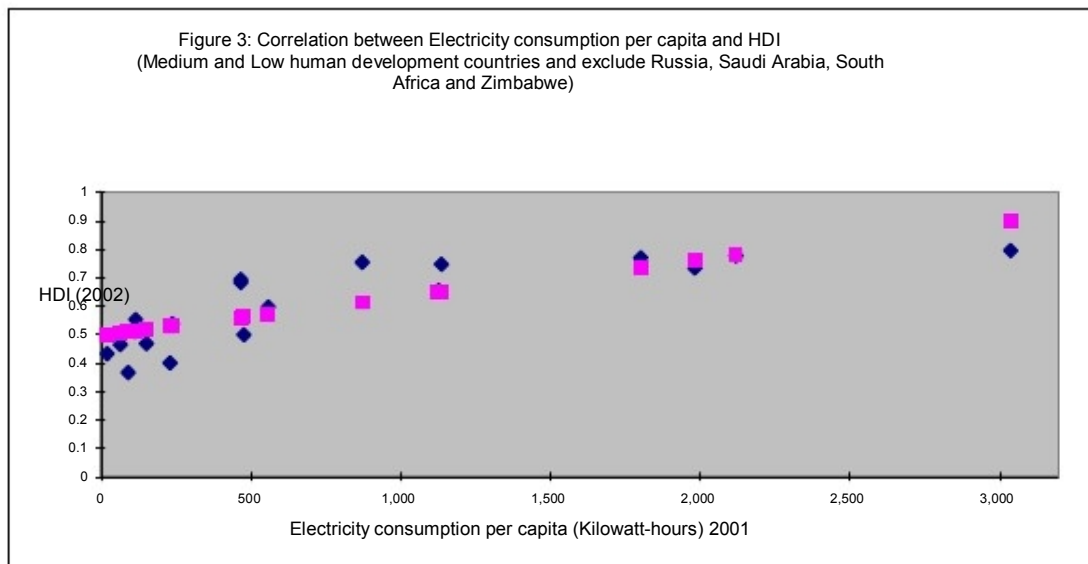(Medium and Low human development countries only)

Once again, the regression test is run with only medium and low human development countries; this time with the four outliers (Russian Federation, Saudi Arabia, South Africa and Zimbabwe) taken out. Even though the final sample now has only 19 countries, the sample size is still sufficient because these 19 countries represent approximately 56.8% of global population. In the regression test result of our final sample, the R square is now equal to 0.6483. This statistic tells us that 64.83% of the variation in the HDI is explained by the variation in the electricity consumption per capita. This R square value is notably higher than our previous R square values. We can see that the relationship between electricity consumption per capita and HDI is very strong after we exclude these four outliers. The remaining 35.17% is still unexplained. The standard error is 0.0865 and average HDI is 0.600158. The standard error of estimate is not negligible, however it is reasonable. We can see these results in Figure 3.

Table 1: 40 original nation sample (Source: UNDP web site)

HIGH		MEDIUM		LOW
Argentina		Bangladesh		Congo, Dem. Rep. of the
Australia		Bhutan		Côte d'Ivoire
Austria		Bolivia		Haiti
Canada		Brazil		Nigeria
France		China		Pakistan
Germany		Egypt		Rwanda
Iceland		India		Zimbabwe *
Italy		Indonesia		
Japan		Iran, Islamic Rep. of		
Korea, Rep. of		Malaysia		
Mexico		Myanmar		
New Zealand		Peru		
Norway		Russian Federation *		
Spain		Saudi Arabia *		
Sweden		South Africa *		
United Kingdom		Thailand		
United States				
* - 4 outliers				
Final 19 countries sample includes all medium and low human development countries less 4 outliers				

Figure 3: Correlation between Electricity consumption per capita and HDI
(Medium and Low human development countries and exclude Russia, Saudi Arabia, South Africa and Zimbabwe)

Now we are going to look at the four countries that seem to show a strange relationship between their HDI and electricity consumption per capita. You'll recall, HDI is a component of three indexes; the Life Expectancy index, Education index and GDP index.

Table 2: HDI in a time line (Source: UNDP web site)

HDI rank (2002)	1975	1980	1985	1990	1995	2000	2002
57 Russian Federation	..	..	..	0.813	0.771	..	0.795
77 Saudi Arabia	0.602	0.656	0.671	0.707	0.741	0.764	0.768
119 South Africa	0.655	0.672	0.697	0.729	0.735	0.69	0.666
147 Zimbabwe	0.547	0.572	0.629	0.617	0.571	0.511	0.491

Table 3: Indicators in 2002 (Source: UNDP web site)

HDI rank (2002)	Electricity consumption per capita(Kilowatt-hours)(2001)	HDI (2002)	Life expectancy index	Education index	GDP index	Life expectancy at birth (2002)	Infant mortality rate (per 1,000 live births) 2002	GDP per capita (PPP US $) 2002	Maternal mortality (Ratio adjusted)(per 100,000 live births) 2002
57 Russian Federation	6,081	0.795	0.69	0.95	0.74	66.7	18	8,230	67
77 Saudi Arabia	6,018	0.768	0.79	0.71	0.81	72.1	23	12,650	23
119 South Africa	4,313	0.666	0.4	0.83	0.77	48.8	52	10,070	230
147 Zimbabwe	950	0.491	0.15	0.79	0.53	33.9	76	2,400	1,100

By looking to the Table 2, we can see that Russian Federation's HDI has notably decreased from 1990 to 2002. Table 3 shows that the education index is very high in Russia, however, the life expectancy and GDP indexes are very low. The collapse of the Soviet Union in 1990 is likely a primary driver of the low life expectancy and GDP indexes. The collapsed economy moves slowly. Unemployment has been very high. The poor economy caused many people to lose their jobs, and thus had little money to buy healthy food and/or health care. These conditions led to desperation and many people turned to hard drinking. Suicide rates increased. This situation began to turn around by the end of the decade. According to CIA World Factbook, "Russia ended 2004 with its sixth straight year of growth, averaging 6.5% annually since the financial crisis of 1998." Russia's GDP index has been increasing since 1998, however the life expectancy index is still low based on its HDI rank in 2002.

Saudi Arabia is a country run primarily by a royal family (see the web site about Saudi Arabia in the bibliography). This huge family is very rich from the ownership of abundant oil resources. According to CIA World Factbook, "This is an oil-based economy with strong government controls over major economic activities." Table 2 shows that Saudi Arabia's HDI has been rising very slowly. We can also see that the GDP index is relatively high and life expectancy index is pretty good in Table 3. The education index, however, is low. It can be surmised that the governing family does not want the general population to become universally educated; as an educated people may be perceived as a threat to their power. Therefore, the education index is artificially suppressed.

South Africa's HDI had been rising until 1995 and then began to decrease significantly through 2002, illustrated in Table 2. The main reason HDI has been decreasing since 1995 is AIDS. In Table 3, we can see that the life expectancy index in 2002 is extremely

low. Many people in South Africa contracted HIV and had AIDS during the late 1990s. This causes the life expectancy index to decrease dramatically. The HIV/AIDS – adult prevalence rate was 21.5% in 2003. South Africa's median age is only 23.98 years in 2005. 50% of South Africa's population was below the poverty line in 2000. We can clearly see that South Africa's HDI is low because a lot of people in South Africa are infected by HIV and AIDS.

Zimbabwe is located just north of South Africa. Its HDI had been rising until 1985 and began to decline through 2002 as illustrated in Table 2. The reason its HDI had been declining since 1985 is a poor economy, and especially AIDS. We can see that its life expectancy index is extremely low and GDP index is also relatively low in 2002 (see Table 3). According to UNDP data for 2002, Zimbabwe had the second lowest life expectancy at birth (33.9) and life expectancy index (0.15) in HDI. According to the CIA World Factbook, Zimbabwe's median age is extremely low at 19.26 years in 2005. The HIV/AIDS – adult prevalence rate was 24.6% in 2002. Besides AIDS, a poor economy is the second problem causing the HDI decrease. According to the CIA World Factbook, "The government of Zimbabwe faces a wide variety of difficult economic problems as it struggles with an unsustainable fiscal deficit, an overvalued exchange rate, soaring inflation, and bare shelves". The GDP real growth rate was -8.2% and inflation rate was 133% in 2004. The unemployment rate is 70% and Zimbabwe has 70% of its population below the poverty line in 2002. Based on the UNDP data and CIA information, we clearly see why Zimbabwe's HDI and other important social development indicators are very low. Therefore, we took out Zimbabwe as an outlier in our statistical analysis.

III. Empirical evidence for the statistical analysis on other social and economic development indicators (using regression test with 19 countries only)
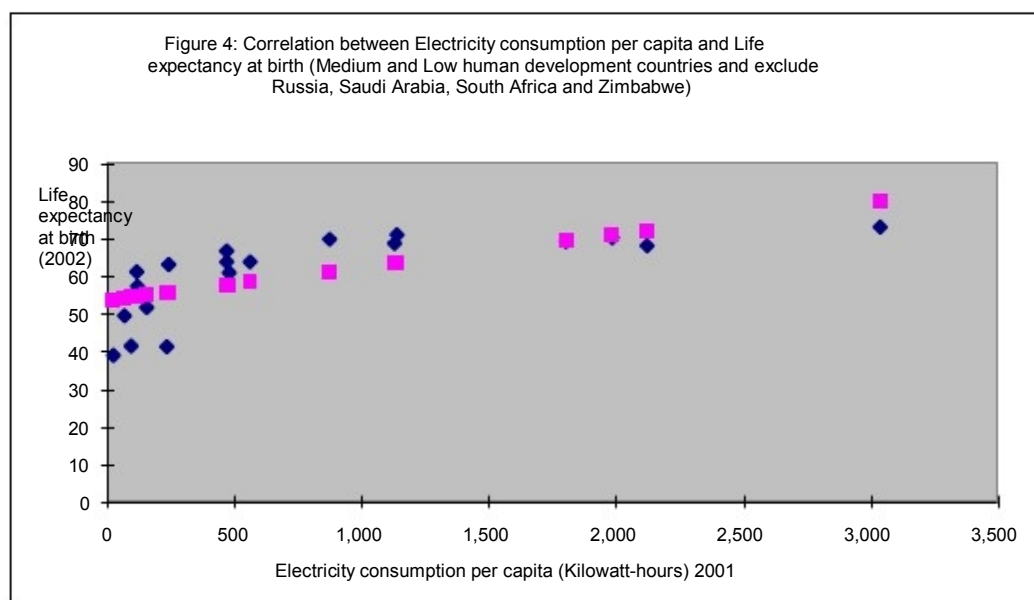
According to the statistical analysis and the descriptions above, we have excluded the high human development countries in the regression analysis because proportional change in HDI and electricity consumption are very different for high human development countries when compared to low human development countries. Moreover, when HDI to electricity consumption per capita for medium and low human development countries is compared, we find that Russian Federation, Saudi Arabia, South Africa, and Zimbabwe have very unique data. Therefore, we chose not include these four outliers in our regression tests. According to the background, social structure, and economics history of these four countries (Russia, Saudi Arabia, South Africa and Zimbabwe), it is reasonable not to include these four countries in our other regression analysis. After we take out all high human development countries and four outliers in our sample, our final sample has just 19 countries. However, our final sample size is still sufficient because these 19 countries represent approximately 56.8% of global population.

Life Expectancy, Infant Mortality Rate, Maternal Mortality

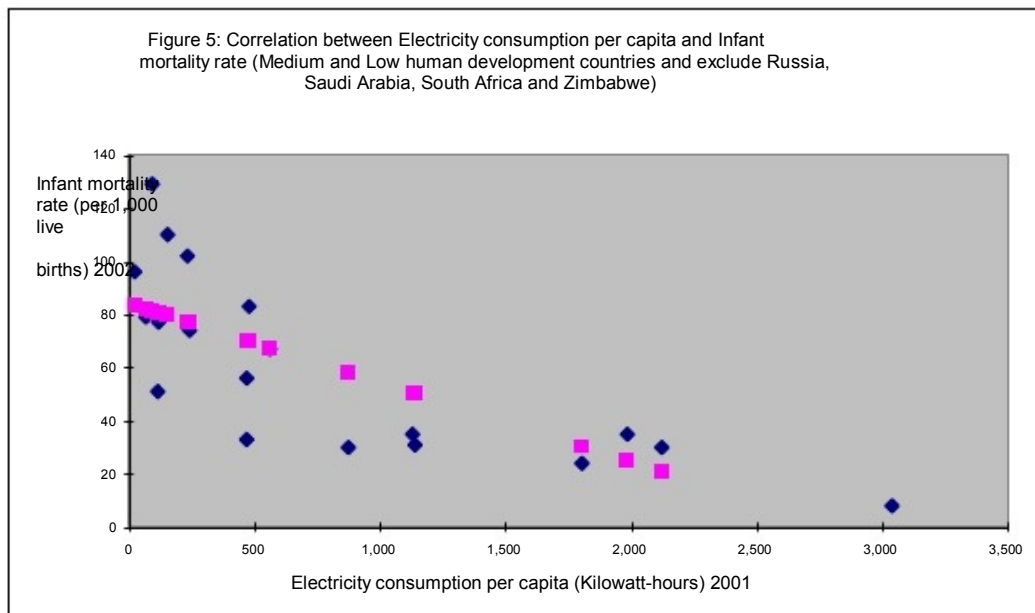Comparing Life expectancy at birth to Electricity consumption per capita:
  We have run a regression test with 19 countries, excluding high human development countries and four outliers described above, in analyzing the correlation between life expectancy at birth and electricity consumption per

capita. We found the result that R square is equal to 0.4769, which tells us that 47.69% of the variation in life expectancy at birth is explained by the variation in the electricity consumption per capita. This R square value is not negligible. Also the standard error is 8.073 and it is still reasonable from the given data. We can see that the relationship between electricity consumption per capita and life expectancy at birth has a certain degree of correlation. We can see this in Fig. 4.

Figure 4: Correlation between Electricity consumption per capita and Life expectancy at birth (Medium and Low human development countries and exclude Russia, Saudi Arabia, South Africa and Zimbabwe)
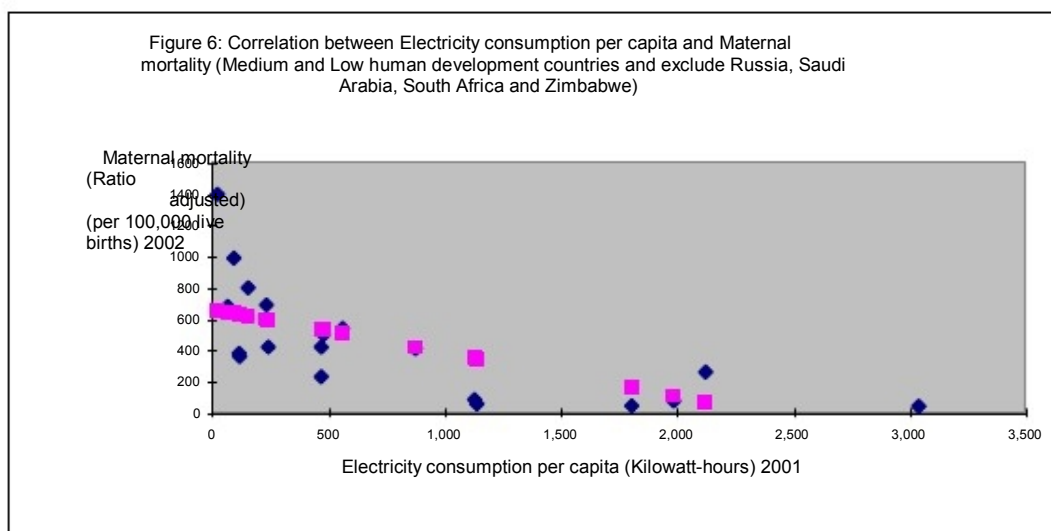
Comparing the Infant mortality rate to Electricity consumption per capita:

A regression test with 19 countries to analyze the correlation between infant mortality rate and electricity consumption per capita has also been performed. The resulting R square is 0.5861, which tells us that 58.61% of the variation in infant mortality rate is explained by the variation in the electricity consumption per capita and 41.39% of the variation in infant mortality rate is explained by other factors. In the many low income countries where electricity consumption per capita is less than 500 kilowatt-hours, IMR fluctuates a lot as there are other factors affecting the infant mortality rate. The R square is significant. Also the standard error is 22.317 and it is still reasonable from the given data. We can see that the relationship between electricity consumption per capita and infant mortality rate is strongly correlated. We can see this in Figure 5.

Figure 5: Correlation between Electricity consumption per capita and Infant mortality rate (Medium and Low human development countries and exclude Russia, Saudi Arabia, South Africa and Zimbabwe)

Comparing Maternal Mortality to Electricity consumption per capita:
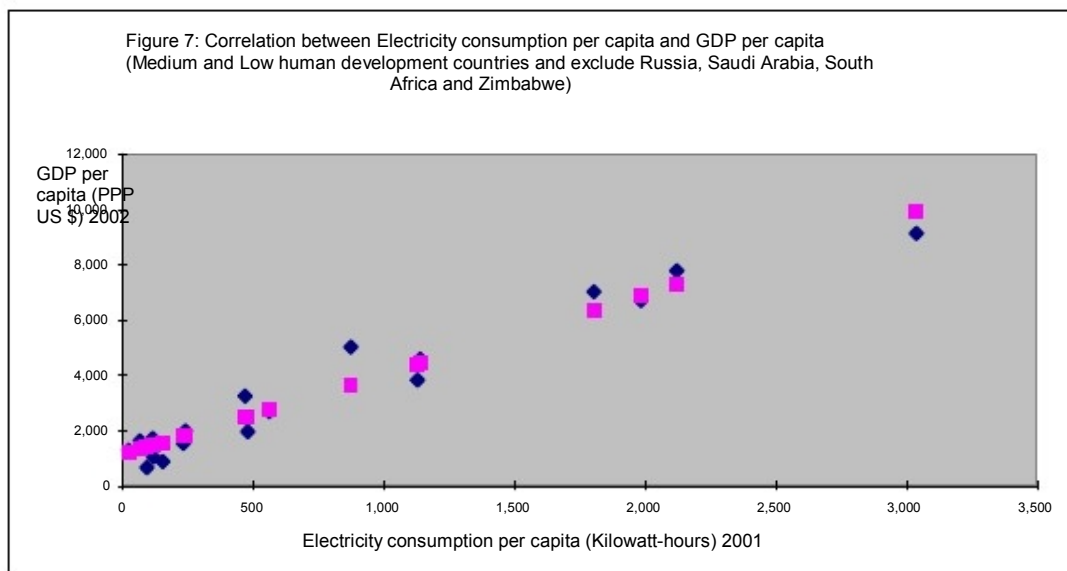
The next regression test is a comparison between maternal mortality and electricity consumption per capita for 19 countries. The R square is 0.4576, which tells us that 45.76% of the variation in maternal mortality is explained by the variation in the electricity consumption per capita. The R square is not immaterial. Moreover, the standard error is 270.802 and it is not negligible, however it is reasonable. We can see that the relationship between electricity consumption per capita and maternal mortality has a fair degree of correlation. We can see this in Figure 6.

Figure 6: Correlation between Electricity consumption per capita and Maternal mortality (Medium and Low human development countries and exclude Russia, Saudi Arabia, South Africa and Zimbabwe)
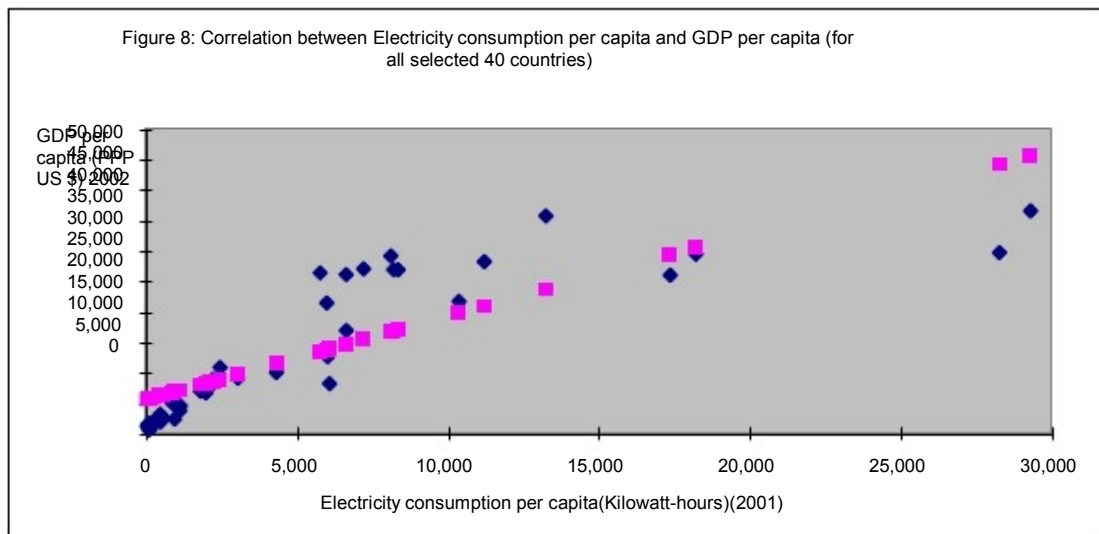
Economic growth indicator: GDP per capita

Comparing GDP per capita to Electricity consumption per capita:

A regression test with 19 countries to analyze the correlation between GDP per capita and electricity consumption per capita produced striking, but expected results. The resulting R square value is 0.9500, which tells us that 95% of the variation in GDP per capita is explained by the variation in the electricity consumption per capita. The R square is extremely high. Also the standard error is 591.98 and it is relatively low from the given data. Therefore, the standard error of estimate is significant. We can see that the relationship between electricity consumption per capita and GDP per capita has an extremely strong correlation. Economic development and electricity seem to go hand in hand. We can see this in Figure 7.

Figure 7: Correlation between Electricity consumption per capita and GDP per capita (Medium and Low human development countries and exclude Russia, Saudi Arabia, South Africa and Zimbabwe)

A regression test to analyze the correlation between GDP per capita and electricity consumption per capita for all selected 40 countries (including high, medium and low human development countries) was also performed. The resulting R square is 0.6932, which tells us that 69.32% of the variation in GDP per capita is explained by the variation in the electricity consumption per capita. The R square is relatively high. Also the standard error is 6617.45 and it is not negligible, however it is reasonable. We can see that the relationship between electricity consumption per capita and GDP per capita is strongly, positively correlated, even including the countries we omitted in our earlier analysis. This is shown here in Figure 8.

9

Figure 8: Correlation between Electricity consumption per capita and GDP per capita (for all selected 40 countries)

GDP per capita (PPP US $)2002

Electricity consumption per capita(Kilowatt-hours)(2001)

IV. Summary

In this paper, we have chosen a group of 40 countries that constitute approximately 76% of the world's population in order to run selected statistical tests and analyze the correlation between electricity consumption per capita and key social and economic indicators.

We began by running a regression test to analyze the strength of the electricity consumption per capita and HDI correlation. However, we realized that high development countries should be excluded in our statistical analysis because the proportion change on HDI and electricity consumption per capita is very different for high human development countries than it is for countries with medium and low human development. Next, we ran a regression test which contained only medium and low human development countries to see how strongly the electricity consumption per capita and HDI are correlated. We realized then that four of the countries had relatively unique data and were in fact statistical outliers. We took these four outliers out of the model and again ran the regression test with 19 countries remained. Doing so resulted in an R square value of to 0.6483, which is not immaterial. This statistic tells us that 64.83% of the variation in the HDI is explained by the variation in the electricity consumption per capita. We can see that the electricity consumption per capita and HDI are highly correlated.

Even though our final sample size has only 19 countries after taking out high human development countries and four outliers, the sample size is still sufficient because these 19 countries represent approximately 56.8% of global population.

Moreover, we ran additional regression tests with these 19 countries for several important social development indicators: life expectancy at birth, infant mortality rate and maternal mortality.

The R square for the regression test between life expectancy at birth and electricity consumption per capita is 0.4769. We can see that there definitely is a certain degree of correlation between life expectancy at birth and electricity consumption per capita.

The R square for the regression test between infant mortality rate and electricity consumption per capita is 0.5861. We can see there is a decent correlation between the infant mortality rate and electricity consumption per capita.

The R square for the regression test between maternal mortality and electricity consumption per capita is 0.4576. We can see that there is a fair correlation between maternal mortality and electricity consumption per capita.

Furthermore, we ran a regression test with 19 countries for an economic development index (GDP per capita). The R square for the regression test between GDP per capita and electricity consumption per capita is 0.9500 and it is extremely high. This led us to run a regression test with all 40 countries to analyze the correlation between GDP per capita and electricity consumption per capita. The R square is 0.6932 and is high enough to conclude that there is an extremely strong correlation between GDP per capita and electricity consumption per capita.

V. Conclusion

According to this empirical analysis, we can see that electricity consumption per capita has a strong correlation to social development indices (HDI, life expectancy at birth, infant mortality rate, and maternal mortality) and especially to economic indices (such as GDP per capita). Increasing electricity consumption per capita can directly stimulate faster economic growth and indirectly achieve enhanced social development--especially for low and medium human development countries. In most cases, the threshold for moving from a low to a medium HDI economy transitions when 500kwh per capita is attained. When this minimal amount of electricity is used for pumping water, providing light, and refrigerating food and medicines, a community can significantly improve their living conditions. Electricity plays a key role in both economic and social development. Hopefully our world leaders can wisely allocate their human, financial and natural resources to achieve these aims.

Future research may consider investigating electricity consumption per capita trended across the decades. This would dynamically show the change between electricity consumption per capita and these social and economic indicators over time. Further study is important to show the general public that increasing electricity consumption per capita has a direct effect on stimulating economic growth and indirectly affect enhanced social development.

Glossary:

HDI: Human Development Index is a summary composite index that measures a country's average achievements in three basic aspects of human development: longevity, knowledge, and a decent standard of living. Longevity is measured by life expectancy at birth; knowledge is measured by a combination of the adult literacy rate and the combined primary, secondary, and tertiary gross enrolment ratio; and standard of living by GDP per capita (PPP US$). HDI is a component of these three indexes (Life expectancy index, Education index and GDP index) (The definition is from UNDP web site.)

R square: measures the variation of y variable is being explained by the variation of x variable, so we can see how well these two variables are correlated

Standard Error: is used to measure the accuracy of the model, the standard error of statistic is the standard deviation of the sampling distribution of that statistic. Standard errors are important because they reflect how much sampling fluctuation a statistic will show (standard error is equal to the average vertical distance from the points to the regression line)

Economic significance: the definition in our paper is to identify the countries on each continent that have the highest GDP for our research sample.

Bibliography:

UNDP web site - United Nations Development Programme (UNDP) is the largest multilateral source of grant technical assistance in the world
http://www.undp.org/

CIA World Factbook - is an annual publication by the Central Intelligence Agency of the United States with basic almanac-style information about the various countries of the world. The factbook gives a two- to three-page summary of the demographics, location, telecommunications capacity, government, industry, military capability, etc, of all US-recognized countries and territories in the world.
http://cia.gov/cia/publications/factbook/index.html

Geography web site - gives a lot of geography information
http://geography.about.com/cs/countries/a/numbercountries.htm

Saudi Arabia web site – information about Saudi Arabia's royal family
http://freedomhouse.org/research/freeworld/2003/countryratings/saudi-arabia.htm

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